ASSESSMENT OF THE EFFICACY, AVAILABILITY AND ENVIRONMENTAL IMPACTS OF BALLAST WATER TREATMENT SYSTEMS FOR USE IN CALIFORNIA WATERS

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EXECUTIVE SUMMARY

The Coastal Ecosystems Protection Act (Act) of 2006 expanded the Marine Invasive Species Act of 2003 to more effectively address the threat of nonindigenous species introduction through ballast water discharge. The Act charged the California State Lands Commission (Commission) to implement performance standards for the discharge of ballast water and to prepare a report assessing the efficacy, availability, and environmental impacts, including water quality, of currently available ballast water treatment technologies. This report summarizes the Commission's findings, discusses future plans of the Commission's Marine Invasive Species Program, and offers recommendations to the Legislature regarding the implementation of performance standards for the discharge of ballast water.

Twenty-eight ballast water treatment systems were evaluated for system efficacy, availability and environmental impacts. Testing was either not performed or data was not available for eight of those systems. For many of the remaining 20, the methods used to evaluate efficacy were variable, and the results were often presented in metrics that were incompatible with California's standards. Thus, it was often impossible to compare the available data for a single system against all of the organism size classes specified by California's performance standards. On a system-by-system basis and across all testing platforms and scales (laboratory, dockside, shipboard), no single technology has yet demonstrated the capability to meet all of California's performance standards.

Since the limited available data indicate that no system demonstrates the capability to meet all seven organism size classes of California's standards, none can be clearly deemed "available" for installation. Efficacy considerations aside however, system availability will also depend on the ability of treatment companies to install sufficient systems on new build vessels, on or after 2009, before those vessels are put into operation. Several companies are, or will soon be capable of producing treatment systems commercially, and it appears that treatment systems will be available in a commercial context. Additional considerations impacting availability include discrepancies between state, federal and international regulation of ballast water management. The demand for treatment systems, and the availability of those systems, will remain questionable until evaluation protocols are developed and legislative issues are settled.

Many ballast water treatment systems utilize “active substances” (i.e. chemicals) to inactivate organisms, requiring an additional level of review for potential environmental impacts. Though the impacts for many such systems have been, or are in the midst of, being evaluated by other governmental entities (International Maritime Organization, Washington State), none have been directly reviewed by the Commission or the State Water Resources Control Board against the water quality regulations and criteria specific to California. Clearly, these impacts should be examined critically, with substantial review from the agency/agencies with the expertise and jurisdiction to ensure that discharges of treated ballast water meet California’s water quality requirements. Establishing an evaluation procedure to assess potential water quality impacts will be as essential as the development of guidelines to assess system efficacy.

Commission staff is currently undertaking several projects to advance the implementation of the interim performance standards and assessment of treatment technologies: 1) Developing guidelines to assist technology developers and ship owners in testing and evaluating treatment systems relative to California’s performance standards; 2) Developing protocols to verify vessel compliance with the performance standards; 3) Working with appropriate California state agencies to identify applicable water quality requirements; and 4) Working with other U.S. West Coast states to align system testing and evaluation guidelines.

In summary, the ability of systems to remove or inactivate organisms from ballast water will likely be at a level to meet California’s performance standards in the near future. However, given the short time remaining before the 2009 implementation of standards for vessels with a ballast water capacity less than 5000 metric tons (MT), and the need to develop efficacy and environmental testing and evaluation procedures before a system should be utilized in California waters, it is unlikely that systems will be sufficiently available soon enough.

The Commission recommends that legislation be adopted to:

1. Change the implementation date for new vessels with ballast water capacity less than 5000 metric tons from 2009 to 2010, and require the Commission to prepare an update of this report on or before January 1, 2009.

No treatment systems currently demonstrate the capacity to meet all of California's standards either due to numerical inability to meet the standards or lack of testing results in metrics comparable to the California standards. Commission staff have begun developing guidelines for the testing and evaluation of treatment systems by technology developers and independent third-party laboratories. Simultaneously, Commission staff are developing protocols to verify vessel compliance with the performance standards and are working in conjunction with the State Water Resources Control Board to identify applicable water quality criteria and regulations. The additional time is requested to ensure that these processes will be complete.

2. Authorize the Commission to amend the ballast water reporting requirements via regulations.

Information will be needed from vessels to support the regulation and enforcement of ballast water discharge standards. As treatment systems come online, it will be important for the Commission to acquire different types of information including the timing of, and requirements for, treatment system use, deviations from suggested system operation, and certifications for operation from vessel classification societies and other organizations/agencies. The Commission should be authorized to amend ballast water reporting requirements to meet these needs.

3. Support continued research promoting technology development.

Ballast water treatment is a fledgling industry that will need to undergo significant development as California's Performance Standards are progressively implemented and as new vessel types are built. The research and development needed to meet these standards will require substantial financial resources, and should be supported by the Legislature.

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ABBREVIATIONS AND TERMS

Act	Coastal Ecosystems Protection Act
CSLC/Commission	California State Lands Commission
Convention	International Convention for the Control and Management of Ships' Ballast Water and Sediments
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
ETV	Environmental Technology Verification Program
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GESAMP-BWWG	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection – Ballast Water Working Group
IMO	International Maritime Organization
MEPC	Marine Environment Protection Committee
Michigan DEQ	Michigan Department of Environmental Quality
MT	Metric Ton
NEPA	National Environmental Policy Act
NIS	Nonindigenous Species
NM	Nautical Mile
NPDES	National Pollution Discharge Elimination System
NRL	Naval Research Laboratory
Panel	Performance Standards Advisory Panel
PRC	Public Resources Code
STEP	Shipboard Technology Evaluation Program
SWRCB	California State Water Resources Control Board
USCG	United States Coast Guard
UV	Ultraviolet Irradiation
WDFW	Washington Department of Fish and Wildlife

I. PURPOSE

This report was prepared for the California Legislature pursuant to the Coastal Ecosystems Protection Act of 2006 (Act). Among its provisions, the Act added Section 71205.3 to the Public Resources Code (PRC) and charged the California State Lands Commission (Commission) to prepare and submit to the Legislature, "a review of the efficacy, availability, and environmental impacts, including the effect on water quality, of currently available technologies for ballast water treatment systems." In preparation of this report, Commission staff conducted a literature review, hosted a workshop with technical experts in ballast water treatment, and consulted a cross-interest, multidisciplinary panel (as required by Section 71205.3 and described in subdivision (b) Section 71204.9 of the PRC). This report summarizes Commission findings and makes recommendations to the Legislature regarding the status and availability of ballast water treatment technologies and the implementation of the interim performance standards for the discharge of ballast water.

II. INTRODUCTION

Nonindigenous Species and their Impacts

Also known as "introduced", "invasive", "exotic", "alien", or "aquatic nuisance species", nonindigenous species (NIS) are organisms that have been transported by human activities to a region where they did not occur historically, and have established reproducing populations in the wild (Carlton 2001). Once established, NIS can have serious human health, economic and environmental impacts in their new environment. The most infamous example is the zebra mussel (*Dreissena polymorpha*), which was introduced to the Great Lakes from the Black Sea in the mid-1980s. This tiny striped mussel attaches to hard surfaces in such dense populations that they clog municipal water systems and electric generating plants, costing approximately $1 billion a year in damage and control (Pimentel et al. 2005). In San Francisco Bay, the overbite clam (*Corbula amurensis*) is thought to have contributed to declines of fish populations in the Sacramento-San Joaquin River Delta by reducing the availability of the plankton food base of the ecosystem (Feyrer et al. 2003). The Chinese mitten crab (*Eriocheir* *sinensis*), first sighted in San Francisco Bay in 1992, clogged water pumping stations and riddled levies with burrows costing approximately $1 million in 2000-2001 for control and research (Carlton 2001). In addition, the microorganisms that cause human cholera (Ruiz et al. 2000) and paralytic shellfish poisoning (Hallegraeff 1998) have been found in the ballast tanks of ships.

In marine, estuarine and freshwater environments, NIS may be transported to new regions through various human activities including aquaculture, the aquarium and pet trade, and bait shipments (Cohen and Carlton 1995, Weigle et al. 2005). In coastal habitats commercial shipping is an important transport mechanism, or “vector,” for invasion. In one study, shipping was responsible for or contributed to approximately 80% of invertebrate and algae introductions to North America (Fofonoff et al. 2003, see also Cohen and Carlton 1995 for San Francisco Bay). Of that, ballast water was a possible vector for 69% of those shipping introductions, making it a significant ship-based introduction vector (Fofonoff et al. 2003).

Ballast water is necessary for many functions related to the trim, stability, maneuverability, and propulsion of large oceangoing vessels (National Research Council 1996). Vessels take on, discharge, or redistribute water during cargo loading and unloading, as they take on and burn fuel, as they encounter rough seas, or as they transit through shallow coastal waterways. Typically, a vessel takes on ballast water after its cargo is unloaded in one port to compensate for the weight imbalance, and will later discharge that water when cargo is loaded in another port. This transfer of ballast water from “source” to “destination” ports results in the movement of many organisms from one region to the next. In this fashion, it is estimated that more than 7000 species are moved around the world on a daily basis (Carlton 1999).

Ballast Water Management

Attempts to eradicate NIS after they have become widely distributed are often costly and unsuccessful (Carlton 2001). Between 2000 and 2006, over $7 million was spent to eradicate the Mediterranean green seaweed (*Caulerpa taxifolia*) from two embayments in southern California (Woodfield 2006). Approximately $10 million is spent annually to control the sea lamprey (*Petromyzon marinus*) in the Great Lakes (Lovell and Stone 2005). From 1999-2006, approximately $6 million was spent to control Atlantic cordgrass (*Spartina alterniflora*) in San Francisco Bay (M. Spellman, pers. comm. 2006). These control costs reflect only a fraction of the cumulative cost over time as species control is an unending process. Prevention is therefore considered the most desirable way to address the NIS issue.

For the vast majority of commercial vessels, ballast water exchange is the primary preventative management technique to prevent or minimize the transfer of coastal (including bay/estuarine) organisms. During exchange, the biologically rich water that is loaded while a vessel is in port or near the coast is exchanged with the comparatively species and nutrient-poor waters of the mid-ocean (Zhang and Dickman 1999). Coastal organisms adapted to the conditions of bays, estuaries and shallow coasts are not expected to survive and/or be able to reproduce in the mid-ocean due to the differences in biology (competition, predation, food availability) and oceanography (temperature, salinity, turbidity, nutrient levels) between the two regions (Cohen 1998). Mid-ocean organisms are likewise not likely to survive in coastal waters (Cohen 1998).

Performance Standards for the Discharge of Ballast Water

Though ballast water exchange is preferable to no ballast water management, it is generally considered an interim tool because of its variable efficacy and operational limitations. Studies indicate that the effectiveness of ballast water exchange at eliminating organisms in tanks ranges widely from 50-99% (Cohen 1998, Parsons 1998, Zhang and Dickman 1999, USCG 2001, Wonham et al. 2001, MacIsaac et al. 2002), however, when performed properly, exchange is an effective tool to reduce the risk of coastal species invasion (Ruiz and Reid 2007). New research also demonstrates that the percentage of ballast water exchanged does not necessarily correlate with a proportional decrease in organism abundance (Choi et al. 2005, Ruiz and Reid 2007). Additionally, some vessels are regularly routed on short voyages or voyages that remain within 50 nautical miles (nm) of shore, and in such cases, the exchange process may create a delay or require a vessel to deviate from the most direct route. Such deviations can extend travel distances, increasing vessel costs for personnel time and fuel consumption.

In some circumstances, ballast water exchange may not be possible without compromising vessel or crew safety. For example, vessels that encounter adverse weather or experience equipment failure may be unable to conduct ballast water exchange safely. Unmanned barges are incapable of conducting exchange without transferring personnel onboard; a procedure that can present unacceptable danger if attempted in the exposed conditions of the open ocean. In recognition of these possibilities, state (California [CA], Oregon [OR], and Washington [WA]) and federal ballast water regulations allow vessels to forego exchange should the master or person in charge determine that it would place the vessel, its crew, or its passengers at risk (CA Assembly Bill: AB 433 [2003], OR Senate Bill: SB 895 [2001], WA Senate Bill 5923 [2007]). Though the provision is rarely invoked in California, the handful of vessels that use it may subsequently discharge un-exchanged ballast into state waters, presenting a risk of NIS introduction.

Both regulatory agencies and the commercial shipping industry have therefore looked toward the development of effective ballast water treatment technologies as a promising management option. For regulators, such systems could provide NIS prevention including in situations where exchange may have been unsafe or impossible. Technologies that eliminate organisms more effectively than mid-ocean exchange could provide a consistently higher level of protection to coastal ecosystems from NIS. For the shipping industry, the use of effective ballast water treatment systems might allow voyages to proceed along the shortest routes, in all operational scenarios, thereby saving time and money.

Despite these incentives, financial investment in the research and development of ballast water treatment systems has been limited and the advancement of ballast water treatment technologies has been slow. Many barriers hinder the development of technologies including the lack of guidelines for testing and evaluating performance, cost of technology development, and equipment design limitations. However, some shipping industry representatives, technology developers and investors considered the absence of a specific set of ballast water performance standards as a primary deterrent to progress. Performance standards would set benchmark levels for organism discharge that a technology would be required to achieve for it to be deemed acceptable for use in California. Developers requested these targets so they could design technologies to meet these standards (MEPC 2003). Without standards, investors were reluctant to devote financial resources towards conceptual or prototype systems because they had no indication that their investments might ultimately meet future regulations. For the same reason, vessel owners were hesitant to allow installation and testing of prototype systems onboard operational vessels. It was argued that the adoption of performance standards would address these fears, and accelerate the advancement of ballast treatment technologies. Thus in response to the slow progress of ballast water treatment technology development and the need for effective ballast water treatment options, state, federal and international regulatory agencies have adopted or are in the process of developing performance standards for ballast water discharges.

III. REGULATORY OVERVIEW

A thorough evaluation of the status of ballast water treatment technologies requires not only an understanding of the regulatory framework associated with the development and implementation of performance standards for the discharge of ballast water, but also knowledge of mechanisms for testing and evaluation of systems to meet those standards. Currently, no comprehensive international, federal or state program exists that includes both performance standards and a mechanism to evaluate technologies to meet those standards. California, other states, the federal government, and the international community are working toward the development of a standardized approach to the management of discharged ballast water however, at this time existing legislation, standards and guidelines vary by jurisdiction. The following is a summary of the status of performance standards regulations and treatment system evaluation as of the writing of this report.

International Maritime Organization

In February 2004 after several years of development and negotiation, International Maritime Organization (IMO) member countries adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments (Convention). Among other requirements, the Convention imposes performance standards for the discharge of ballast water (Regulation D-2) with an associated implementation schedule based on vessel ballast water capacity and status as a new or existing vessel (Tables III-1 and III-2).

The Convention will enter into force 12 months after ratification by 30 countries representing 35% of the world's commercial shipping tonnage (IMO 2005). As of September 30, 2007, only 10 countries (Barbados, Egypt, Kiribati, Maldives, Nigeria, Norway, Spain, St. Kits and Nevis, Syrian Arab Republic, and Tuvalu) representing 3.42% of the world's shipping tonnage have signed the convention (IMO 2007).

Guidelines for the evaluation and approval of ballast water treatment systems were adopted at the 53rd session of the IMO Marine Environment Protection Committee (MEPC) in July, 2005. Guideline G8, "Guidelines for Approval of Ballast Water Management Systems" (MEPC 2005a), and Guideline G9, "Procedure for Approval of Ballast Water Management Systems That Make Use of Active Substances" (MEPC 2005b), work together to create a framework for the evaluation of treatment systems by the MEPC and Flag State Administrations (i.e. the country or flag under which a vessel operates) (Figure III-3). Flag States (not the IMO) may grant approval (also known as "Type Approval") to systems that are in compliance with the Convention's Regulation D-2 performance standards based on recommended procedures (as detailed in Guideline G8) for full-scale land-based (testing involving equivalent volume and ballast flow rate as on a vessel) and shipboard testing of the treatment system.

Table III-1. Ballast Water Treatment Performance Standards

Organism Size Class	IMO Regulation D-2[1]	California[1,2]		Washington
Organisms greater than 50 µm[3] in minimum dimension	< 10 viable organisms per cubic meter	No detectable living organisms		Technology to inactivate or remove: 95% zooplankton 99% bacteria and phytoplankton
Organisms 10 – 50 µm[3] in minimum dimension	< 10 viable organisms per ml[4]	< 0.01 living organisms per ml[4]		
Organisms less than 10 µm[3] in minimum dimension		< 10^3 bacteria/100 ml[4] < 10^4 viruses/100 ml[4]		
Escherichia coli	< 250 cfu[5]/100 ml[4]	< 126 cfu[5]/100 ml[4]		
Intestinal enterococci	< 100 cfu[5]/100 ml[4]	< 33 cfu[5]/100 ml[4]		
Toxicogenic *Vibrio cholerae* (01 & 0139)	< 1 cfu[5]/100 ml[4] or < 1 cfu[[5]/gram wet weight zooplankton samples	< 1 cfu[5]/100 ml[4] or < 1 cfu[5]/gram wet weight zoological samples		

[1] See Implementation Schedule (below) for dates by which vessels must meet California Interim Performance Standards and IMO Ballast Water Performance Standard
[2] Final discharge standard for California, beginning January 1, 2020, is zero detectable living organisms for all organism size classes
[3] Micrometer – one-millionth of a meter
[4] Milliliter – one-thousandth of a liter
[5] Colony-forming-unit – a measure of viable bacterial numbers

Table III-2. Implementation Schedule for Performance Standards

Ballast Water Capacity of Vessel	Standards apply to new vessels in this size class constructed on or after	Standards apply to all other vessels in this size class beginning in
< 1500 metric tons	2009	2016
1500 – 5000 metric tons	2009	2014
> 5000 metric tons	2012	2016

In addition to receiving Type Approval from the Flag State Administration, the Convention specifies that ballast water treatment systems using "active substances" must be approved by IMO based upon procedures developed by the organization (IMO 2005). An active substance is defined by IMO as, "…a substance or organism, including a virus or a fungus that has a general or specific action on or against Harmful Aquatic Organisms and Pathogens" (IMO 2005). For all intents and purposes, an active substance is a chemical or reagent (e.g. chlorine, ozone…) that kills or deactivates species in ballast water. The IMO approval pathway for systems that utilize active substances to inactivate or kill organisms in ballast water is more rigorous than the evaluation process for technologies that do not. As required by Guideline G9, technologies utilizing active substances must go through a two-step "Basic" and "Final" approval process. Active substance systems that apply for Basic and Final Approval are reviewed for environmental, ship, and personnel safety by the IMO Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) – Ballast Water Working Group (BWWG) in accordance with the procedures detailed in Guideline G9. The MEPC may grant Basic or Final Approval based upon the GESAMP-BWWG recommendation. Systems that do not use active substances do not need Basic or Final Approval, and need only acquire Type Approval (i.e. a system only using filtration would not need Basic or Final Approval).

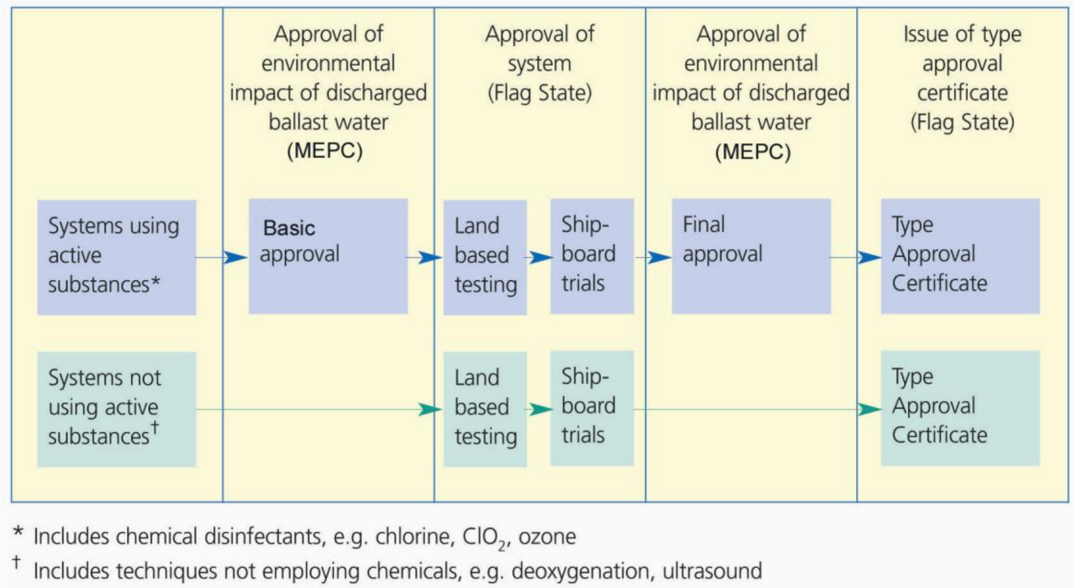

Figure III-3. Summary of IMO approval pathway for ballast water treatment systems. (Modified from Lloyd's Register (2007))

The entire IMO evaluation process (including approval for systems using active substances) has been estimated to take anywhere from six months to two years to complete (R. Everett, pers. comm. 2007, Lloyd's Register 2007). Once a ballast water treatment system has acquired Type Approval (and the Convention is ratified and in force), the system is deemed acceptable by parties to the Convention for use in international waters in compliance with Regulation D-2.

The U.S. has neither reviewed nor submitted applications to IMO on behalf of any U.S. treatment technology developers thus far. Until the Convention is both signed by the U.S. and enters into force through international ratification, no U.S. federal agency has the authority (unless authorized by Congress) to manage a program to review treatment technologies and submit applications on their behalf to IMO. United States treatment developers may approach IMO through association with international companies. One U.S. technology developer has joined forces with a Korean company that has received Basic Approval under the Korean flag, and another U.S. developer has received Type Approval (the only Type Approval granted to date) through the Liberian Flag State Administration (R. Everett pers. comm. 2007). However, because the Convention has not yet been ratified, it does not have the force of international law, which draws into question the legality of IMO approvals of treatment systems. While the U.S. is actively involved in developing and negotiating the various requirements of the Convention, until the U.S. signs on, it is not party to the Convention requirements. Hence, vessels calling on U.S. ports have no right to use IMO-approved systems to meet U.S. ballast water management requirements.

Federal Legislation and Programs

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, revised and reauthorized as the National Invasive Species Act of 1996, provides authority to the United States Coast Guard (USCG), through the Department of Homeland Security, to regulate the management of ballast water in the United States. Included in the legislation is the authority to approve ballast water management systems that are at least as effective as ballast water exchange. As mentioned in the Introduction (Section II), the efficacy of ballast water exchange is highly variable, and thus the USCG believes the only way to consistently ensure that treatment systems are at least as effective as exchange is to set a discharge performance standard (USCG 2007). The USCG began this rulemaking process in 2002, but has yet to set a discharge standard. The lack of a federal discharge standard precludes the approval of any treatment system at the national level.

Several bills have been introduced in the House and Senate in recent years to legislatively establish a national discharge standard. In 2007 the following bills were introduced:

- The Ballast Water Management Act of 2007 (H.R. 2423, S. 1578)
- Prevention of Aquatic Invasive Species Act of 2007 (H.R. 889)
- National Aquatic Invasive Species Act of 2007 (S. 725)
- Great Lakes Invasive Species Control Act (H.R. 801)
- Coast Guard Authorization Act of 2007 (H.R. 2830)
- Great Lakes Collaboration Implementation Act (S. 791, H.R. 1350)
- Aquatic Invasive Species Research Act (H.R. 260).

These bills seek to clarify the goals and role of the federal government in ballast water management. Several of the bills introduce performance standards that would be less stringent than California's standards. More importantly, however, many of these bills also introduce language that would preempt California law and set back California's efforts to better control ballast water discharge and other ship-mediated vectors of NIS introductions. Staff will continue to follow and assess the potential impacts of any new federal legislation on ballast water management and California's program. As of November, 2007, no legislation has passed.

Two promising federal programs that are currently working proactively to support the development of experimental treatment technologies and facilitate the testing and evaluation of those systems are the USCG Shipboard Technology Evaluation Program (STEP) and the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) program. The USCG Shipboard Technology Evaluation Program (STEP) is intended to facilitate the development of ballast water treatment technologies. Vessel owners and operators accepted into STEP may install and operate specific experimental ballast water treatment systems on their vessels for use in U.S. waters. In order to be accepted, treatment technology developers must assess: the efficacy of systems for removing biological organisms, residual concentrations of treatment chemicals, and water quality parameters of the discharged ballast water (USCG 2004). STEP provides incentives for vessel operators and treatment developers to test promising new technologies. Vessels accepted into the program may be grandfathered for operation under future ballast water discharge standards for the life of the vessel or the treatment system. However, in the three years that the program has been in existence, none of the three vessels that have applied have yet received notice of STEP approval.

The EPA Environmental Technology Verification (ETV) program is an effort to accelerate the development and marketing of environmental technologies, including ballast water treatment technologies. The USCG and the EPA established a formal agreement to implement an ETV program focused on ballast water management. Under this agreement, the ETV Program developed draft protocols for verification of the performance of ballast water treatment technologies. Subsequently, the USCG established an agreement with the Naval Research Laboratory (NRL) to evaluate, refine, and validate the protocols and the test facility design required for their use. This validation project has resulted in the construction of a model ETV Ballast Water Treatment System Test Facility at the NRL Corrosion Science and Engineering facility in Key West, Florida. The innovative research conducted by the USCG, EPA and NRL within the ETV Program and at the NRL facility is intended by the USCG to result in technical procedures for testing ballast water treatment systems for the purpose of approval and certification.

The Shifting Federal Landscape

While the USCG (including the STEP and ETV programs) is moving forward to establish performance standards and evaluate treatment technologies, the authority to manage ballast water at the federal level is currently under debate in the courts. This decision could have a major impact on the establishment of performance standards and the assessment of treatment systems both at the federal and state level. In 2003, Northwest Environmental Advocates et al., filed suit in U.S. District Court, Northern District of California, against the U.S. EPA challenging a regulation originally promulgated under the Clean Water Act (CWA). The regulation at issue, 40 C.F.R. Section 122.3(a), exempts effluent discharges "incidental to the normal operations of a vessel" from regulation under the National Pollution Discharge Elimination System (NPDES). The plaintiffs sought to have the regulation declared *ultra vires,* or beyond the authority of the EPA under the CWA. On March 31, 2005, the District Court granted judgment in favor of Northwest Environmental Advocates et al. On September 18, 2006 the Court issued an order revoking the exemptive regulation (40 C.F.R. Section 122.3(a)) as of September 30, 2008. The ruling requires the EPA to develop a system, presumably as part of the NPDES permit process, which would require ballast water to be discharged under certain parameters. EPA has filed an appeal with the Ninth Circuit U.S. Court of Appeals, which is still pending.

Ultimately, this court decision will impact not only who regulates ballast water at the federal and state levels, but how they do so. The implementation of an NPDES permit process for vessel discharges may require a region by region (water basin by water basin) assessment of total allowable NIS concentrations, which could potentially result in the application of different discharge standards for different water bodies. Under such a situation, a vessel could be required to meet a different standard at each port of arrival, even within a single U.S. state. This would very likely impact ballast water performance standards currently established by states, and could also impact a vessel's selection and use of technologies to meet those standards. In practice, a vessel may have to utilize a treatment system that meets the strictest standard in effect at any port it may visit.

U.S. States

Washington

In 2001, the Washington Department of Fish and Wildlife (WDFW) established interim ballast water discharge standards to provide a target for technology developers (WAC 220-77-095). The standard requires the inactivation or removal of 95 percent of zooplankton and 99 percent of phytoplankton and bacteria in ballast water. WAC 220-77-095 also established an interim approval process for use of ballast water treatment systems in Washington waters (only USCG-approved systems may be used to meet federal requirements) which was revised by Emergency Rule (WAC 220-77-09500A), effective August 17, 2007. Systems may be approved for use on specified vessels contingent upon meeting one or more of the following criteria: 1) Previously approved by the WDFW for use in Washington waters; 2) Approved by USCG for use in national waters; 3) Enrolled in the USCG STEP; 4) Approved by the State of California for use in California waters; 5) Approved by IMO; or 6) Enrolled in the IMO approval process. Technologies are also evaluated for water quality standards as necessary.

Michigan

Michigan passed legislation in June 2005 (Act 33, Public Acts of 2005) requiring a permit for the discharge of any ballast water from oceangoing vessels into the waters of the state beginning January 2007. Through the general permit (Permit No. MIG140000) developed by Michigan Department of Environmental Quality (DEQ), any ballast water discharged must first be treated by one of four methods (hypochlorite, chlorine dioxide, ultraviolet radiation preceded by suspended solids removal, or deoxygenation) that have been deemed environmentally sound and effective in preventing the discharge of NIS. Vessels must use treatment technologies in compliance with applicable requirements and conditions of use as specified by Michigan DEQ for use in Michigan waters. Vessels using technologies not listed under the Michigan general permit may apply for individual permits if the treatment technology used is, “environmentally sound and its treatment effectiveness is equal to or better at preventing the discharge of aquatic nuisance species as the ballast water treatment methods contained in [the general] permit,” (Michigan DEQ 2006). Other Great Lakes states are considering similar legislation.

California

California’s Marine Invasive Species Act of 2003 (Section 71204.9 of the PRC) directed the Commission to recommend performance standards for the discharge of ballast water to the State Legislature in consultation with the State Water Resources Control Board (SWRCB), the USCG and a technical advisory panel (Panel). The legislation also directed that standards should be selected based on the best available technology economically achievable, and should be designed to protect the beneficial uses of the waters of the State. Commission staff therefore convened a cross-interest, multi-disciplinary panel and facilitated discussion over the selection of standards during five meetings held during 2005 prior to preparing the report (Falkner et al. 2006) required by the Legislature.

A variety of approaches were used to guide the selection of standards: biological data on organism concentrations in exchanged and un-exchanged ballast water, theories on coastal invasion rates, standards considered or adopted by other regulatory bodies, and available information on the efficacy and costs of experimental treatment technologies. Though each topic provided some level of insight, none could provide solid guidance for the selection of a specific set of standards. At a minimum, it was determined that reductions achieved by California’s performance standards should improve upon the status quo and decrease the discharge of viable ballast organisms to a level below quantities observed following legal ballast water exchange. Additionally, the technologies used to achieve these standards should function without introducing chemical or physical constituents to the treated ballast water that may result in adverse impacts to receiving waters. Beyond these general criteria, however, there was no concrete support for the selection of a specific set of standards. This stems from the key knowledge gap that invasion risk cannot be predicted for a particular quantity of organisms discharged in ballast water (MEPC 2003), with the exception that zero organism discharge equates to zero risk.

The Commission ultimately put forward performance standards recommended by the majority of the Panel because they encompassed several desirable characteristics: 1) A significant improvement upon ballast water exchange; 2) In-line with the best professional judgment from scientific experts that participated in the IMO Convention; and 3) Approached a protective zero discharge standard. The proposed interim standards were based on organism size classes (Table III-1). The standards for the two largest size classes of organisms (>50 µm in minimum dimension and 10 – 50 µm in minimum dimension) were significantly more protective than those proposed by the IMO Convention. The majority of the Panel also recommended standards for organisms less than 10 µm including human health indicator species and total counts of all living bacteria and viruses. The recommended bacterial standards for human health indicator species, *Escherichia coli* and intestinal enterococci, are identical to those adopted by the EPA in 1986 for recreational use and human health safety (EPA 1986). The standard for total living bacteria and viruses has not been considered or adopted by any other state, federal or international administration or agency. The standard will require an assessment of viability and the quantification of bacteria and viruses, and currently there are no widely accepted methods for either. The implementation schedule proposed for the interim standards was identical to the IMO Convention (Table III-2). A final discharge standard of zero detectable organisms was recommended by the majority of the Panel with an implementation deadline of 2020 added by the Commission.

The Commission submitted the recommended standards and information on the rationale behind its selection in a report to the State Legislature in January of 2006 (Falkner et al. 2006). By the fall of that same year, the Legislature passed the Coastal Ecosystems Protection Act (SB 497) directing the Commission to adopt the recommended standards and implementation schedule through the California rulemaking process by January 1, 2008. The Commission completed that rulemaking process in October, 2007.

In anticipation of the first implementation date of the interim performance standards in 2009 for new vessels with a ballast water capacity less than 5000 metric tons (MT), the Coastal Ecosystems Protection Act also directed the Commission to review the efficacy, availability and environmental impacts of currently available ballast water treatment systems. The initial review (this report) must be submitted to the State Legislature by January 1, 2008. Additional reviews must also be completed 18 months before the implementation dates for other vessel classes, and also 18 months prior to the implementation of the final discharge standard on January 1, 2020 (see Table III-2 for full implementation schedule). During any of these reviews if it is determined that existing technologies are unable to meet the discharge standards, the report must describe why they are not available.

As of the writing of this report, Commission staff is in the midst of developing two sets of guidelines/protocols: 1) Treatment technology testing and evaluation guidelines, and 2) Procedures for the verification of compliance with the performance standards. The treatment technology testing and evaluation guidelines will be a set of preferred methods for system assessment that technology developers and third-party laboratories may use to test their systems for potential compliance with California's standards. The Commission does not intend to pre-approve technologies for use in California waters. Instead, these guidelines will allow developers to self-certify that their systems will meet

California’s requirements. While testing according to these guidelines will not be legally required, the guidelines will help to support quality product testing and evaluation. Self-certification by technology developers will assure vessel owners and operators that they are investing in a system that will meet California’s discharge requirements. Testing conducted under the Commission’s guidelines will also help Commission staff assess the efficacy and future availability of treatment systems to meet California’s standards. Staff expects these guidelines to be completed in 2008.

Staff is also developing protocols to verify vessel compliance with the discharge standards. These will be used by inspectors to fulfill Section 71206(a) of the PRC, requiring the Commission to sample ballast water from at least 25% of vessels for compliance with the law. The development of these protocols will involve consideration of the best available sampling techniques and technologies, ease of use, cost effectiveness, accuracy and precision. Commission staff is working with the USCG, the Smithsonian Environmental Research Center, the NRL Ballast Water Treatment System Test Facility, and others on the development of verification protocols. Prior to implementation, the protocols will need to be codified through the rulemaking process, and Staff expects this to be completed in late-2008.

Though Staff continues to develop and implement guidelines and procedures to evaluate treatment system performance and compliance, the outcome of the Federal EPA/Clean Water Act court case will likely impact the administration of ballast water management. The potential impacts on California’s ballast water program are currently unclear. The SWRCB is the state agency responsible for implementing the federal CWA including activities such as setting water quality standards, developing water quality control plans and issuing NPDES permits. However, under California’s Coastal Ecosystems Protection Act, no state agency can impose requirements, “pertaining to the discharge or release of ballast water and other vectors of nonindigenous species from a vessel regulated pursuant to this division,” unless mandated by Federal law (PRC Section 71207(a)). Should the SWRCB determine that the EPA court ruling constitutes a federal mandate, they could attempt to regulate ballast water discharges under the State's NPDES program. As a result, the Commission's Marine Invasive Species Program will be affected, with the potential that the program could be partially or wholly discontinued, with the SWRCB implementing its own, potentially unfunded, program. Legislation may be required to clarify how the programs will operate within the new legal environment. Despite the uncertain legal situation, the Marine Invasive Species Program will continue to move forward to fulfill its mandates under the Coastal Ecosystems Protection Act.

IV. TREATMENT TECHNOLOGY ASSESSMENT PROCESS

Public Resources Code (PRC), Section 71205.3 directs the Commission to prepare, "a review of the efficacy, availability, and environmental impacts, including the effect on water quality, of currently available technologies for ballast water treatment systems." In accordance with the law, the Commission shall consult with, "the State Water Resources Control Board, the United States Coast Guard, and the stakeholder advisory panel described in subdivision (b) of Section 71204.9" of the PRC. This panel provided guidance in the development of the performance standards report to the California Legislature (Falkner et al. 2006).

The Commission conducted an exhaustive literature search of available scientific papers, gray literature (i.e. a study or report not published in a peer-reviewed journal), white papers including reports that describe and discuss the complex process of treatment technology evaluation (USCG 2004, PSMFC 2006), and company promotional materials related to ballast water treatment technologies. Staff also contacted treatment technology developers in order to gather additional information about system development and testing. Commission staff summarized available information on treatment systems and developed a treatment system matrix (see Tables V-1, VI-1, VI-3, VI-4, and Appendix A). Prior to consulting with the larger stakeholder advisory panel, Staff received input from a small technical workgroup.

Commission staff invited a small group of technical and scientific experts to participate in a half-day workshop in May 2007 to assess the current availability of treatment systems, their ability to meet the California performance standards, the efficacy of these systems, and environmental and water quality impacts. This group included individuals with expertise in ballast water treatment technology development, water quality and biological testing, naval architecture, naval engineering, and technology efficacy testing (see Appendix B for list of workshop participants).

In preparation for the workshop, participants were asked to review several tables summarizing relevant treatment system information and be prepared to address the following questions:

- What is the efficacy of existing treatment systems? Can any system meet California's performance standards? If not, why not?
- What is the availability of existing treatment systems? Have any treatment systems been approved at the state, federal or international level? Are any systems commercially available? If they are not ready now, when?
- What are the environmental impacts, if any, of existing systems? Are there standard testing protocols to assess environmental impacts? Have any systems undergone rigorous testing, including system safety testing? What agencies have jurisdiction/expertise over testing?

Workshop consensus (see Appendix B for workshop summary) regarding the biological efficacy was that most treatment systems, particularly those using biocides, would be capable of meeting California's performance standards. However, two major challenges associated with assessing treatment efficacy need to be addressed: 1) The lack of available results demonstrating treatment system performance at appropriate vessel-size scale, and 2) The lack of standardized tests and procedures necessary to determine whether or not treated ballast water meets the performance standards. Additional challenges identified included: the lack of sufficient toxicological testing; the lack of comprehensive cost data for system purchase, installation and operation; and the limited numbers of treatment technologies evaluated.

Additional input was received from the larger stakeholder advisory panel (see Appendix C for list of Panel members), SWRCB and USCG. The Advisory Panel met in October, 2007 (see Appendix C for meeting participants and notes), and discussions and areas of agreement were then considered by Staff to help guide the development of the final report.

V. TREATMENT TECHNOLOGIES

The goal of ballast water treatment is to remove or inactivate organisms entrained in ballast water. While this may appear simple given societal experience with waste water treatment technologies, the design and production of ballast water treatment systems can be difficult and complex in practice. A system must be effective under a wide range of challenging environmental conditions including variable temperature, salinity, nutrients and suspended solids. It must also function under difficult operational constraints including high flow-rates of ballast water pumps, large water volumes, and variable retention times (time ballast water is held in tanks). Treatment systems must be capable of eradicating a wide variety of different organisms ranging from viruses and microscopic bacteria to free-swimming plankton, and must operate so as to minimize or prevent impairment of the water quality conditions of the receiving waters. The development of effective treatment systems is further complicated by the variability of vessel types, shipping routes and port geography.

Two general platform types have been explored for the development of ballast water treatment technologies. Shoreside ballast water treatment occurs at a shore-based facility following transfer from a vessel. Shipboard treatment occurs onboard operating vessels through the use of technologies that are integrated into the ballasting system. While shipboard treatment systems are attractive because they allow more flexibility to manage ballast water during normal operations, there continues to be some interest in the development of shoreside treatment options for ballast water.

The similarity of shoreside treatment to waste water treatment makes it seem like an appealing option, however, it poses several challenges for treating vessel ballast water. Current wastewater treatment plants are not equipped to treat saline water (SWRCB 2002, S. Moore pers. comm.). If existing municipal facilities are to be used for the purposes of ballast water treatment, they will need to be modified, and a new extensive network of piping and associated pumps will be required to distribute ballast water from vessels at berth to the treatment plants. The establishment of new piping and facilities dedicated to ballast water treatment, while technically feasible, would be complex and costly in California port areas. Shoreside treatment is not feasible for vessels that must take on or discharge ballast water while underway, for example, if the vessel must adjust its draft to navigate through a shallow channel or under a bridge. The retrofit of vessels including pumps, piping and valves necessary to discharge ballast to a shoreside facility at a flow rate that prevents vessels delays might also be cost prohibitive (CAPA 2000). Shoreside treatment should be considered for unique terminals, those with limited but dedicated vessel calls (such as cruise ships).

To date only limited feasibility studies have been conducted for the shoreside treatment option (see references in Falkner et al. 2006). One study specific to cruise ships indicated that due to the operational practices of cruise ships and the current regulatory requirements in California and the Port of San Francisco there is little demand at this time for shoreside treatment except in emergency situations (Bluewater Network 2006). Additional studies are necessary to determine shoreside demand for other vessel types across the state as a whole.

The majority of time, money, and effort in the development of ballast water treatment technologies during recent years has been focused on shipboard treatment systems. Further study of onshore treatment would be helpful to assess its future potential role in solving California's ballast water problem. This may include assessments by those involved in the wastewater treatment sector on whether existing technologies could meet California's performance standards. However, because all prototype technologies to date have been ship-based, we focus solely on shipboard systems for the remainder of this report.

Shipboard systems allow for greater flexibility during vessel operations. Vessels may treat and discharge ballast while in transit, and thus will not need to coordinate vessel port arrival time with available space and time at shoreside treatment facilities. As with shoreside treatment, however, shipboard treatment systems face their own set of challenges. They must be engineered to conform to a vessel's structure, ensure crew safety, and withstand the vibrations and movements induced by the vessel's engine or rough seas. Additionally, shipboard systems must be effective under transit times that range from less than 24 hours to several weeks, and must ensure that treated water meets all water quality requirements in recipient regions upon discharge.

The timing and location of shipboard ballast water treatment can be varied according to the needs of the treatment system and the length of vessel transit. Ballast water may be treated in the pipe during uptake or discharge (in line) or in the ballast tanks during the voyage (in tank). While mechanical separation (such as filtration) generally occurs during ballast uptake in order to remove large organisms and sediment particles before they enter the ballast tanks, other forms of treatment may occur at any point during the voyage. Some treatment systems treat ballast water at multiple points during the voyage, such as during uptake and discharge.

Because of this wide range of variables associated with shipboard ballast water treatment, the identification of a single treatment technology for all NIS, ships, and port conditions is unlikely. Each technology will meet the objective of killing or deactivating NIS in a slightly different manner and each could potentially impact the waters of the receiving environment through the release of chemical residuals or alterations to water temperature, salinity, and/or turbidity. Thus a suite of treatment technologies will undoubtedly need to be developed to treat ballast water industry-wide and across all ports and environments.

Treatment Methods

The development of ballast water treatment systems that are effective, environmentally friendly and safe has been a complex, costly and time consuming process. At the root of many of treatment systems are methods that are already in use to some degree by the waste water treatment industry. A preliminary understanding of these treatment methods forms the basis for more detailed analysis and discussion of ballast water treatment systems. The diverse array of water treatment methods currently under development for use in ballast water treatment can be broken down into four major categories: mechanical, chemical, physical, and combined.

Mechanical Treatment

Mechanical treatment traps and removes mid-size and large particles from ballast water. Mechanical treatment typically takes place upon ballast water uptake in order to limit the number of organisms and amount of sediment that may enter ballast tanks. Options for mechanical treatment include filtration and hydrocyclonic separation.

Filtration works by capturing organisms and particles as water passes through a porous screen or filtration medium, such as sand or gravel. The size of organisms trapped by the filter depends on the mesh size in the case of screen or disk filters, and on the size of the interstitial space for filtration media. In ballast water treatment, screen and disk filtration is more commonly used over filter media, however, there has been some interest in the use of crumb rubber as a filtration medium in recent studies (Tang et al. 2006). Typical mesh size for ballast water filters ranges from 25 to 100 µm (Parsons and Harkins 2002, Parsons 2003). Most filtration-based technologies also use a backwash process that removes organisms and sediment that become trapped on the filter, and can discharge them at the port of origin before the vessel gets underway. Filter efficacy is a function not only of initial mesh size, but also of water flow rate and backwashing frequency.

Hydrocyclonic separation, also known as centrifugation, relies on density differences to separate organisms and sediment from ballast water. Hydrocyclones create a vortex that cause heavier particles to move toward the outer edges of the cyclonic flow where they are trapped in a weir-like device and can be discharged before entering the ballast tanks (Parsons and Harkins 2002). Hydrocyclones in use in ballast water treatment trap particles in the 50 to 100 µm size range (Parsons and Harkins 2002). One challenge associated with hydrocylone use, however, is that many small aquatic organisms have a density similar to sea water and are thus difficult to separate using centrifugation.

Chemical (Biocide) Treatment

A variety of chemical biocides are available to kill or inactivate organisms in ballast water. Biocides may be used during ballast uptake, vessel transit, or discharge. Biocides can be classified into two major categories: oxidizing and non-oxidizing. Oxidizing agents (e.g. chlorine, chlorine dioxide, bromine, hydrogen peroxide, peroxyacetic acid, ozone) are commonly used in the waste-water treatment sector and work by destroying cell membranes and other organic structures (NRC 1996, Faimali et al. 2006). Non-oxidizing biocides, including Acrolein®, gluteraldehyde, and menadione (Vitamin K3), are reported to work like pesticides by interfering with neural, reproductive or metabolic processes (NRC 1996, Faimali et al. 2006).

As with any biocide, the ultimate goal of these products is to maximize killing efficacy while minimizing environmental impact. Environmental concerns surrounding biocide use in ballast water focus on chemical residuals that may be present in ballast water at the time of discharge. The effective use of biocides in ballast water treatment requires a balance between the amount of time required to achieve deactivation of organisms, with the time needed for biocides to degrade, or for residuals to be treated, to environmentally acceptable levels. Both of these times vary as a function of ballast water organic content and sediment load. As a result, certain biocides may be more effective than others based on ballast volume, voyage length, and water quality conditions. Additional concerns about biocide use specific to shipboard operation include corrosion, safety (personnel and ship safety), and vessel design limitations that impact the availability of space onboard for both chemical storage and equipment for chemical dosing.

Physical Treatment

Physical treatment methods include a wide range of non-chemical means to kill or deactivate organisms present in ballast water. Like chemical treatment, physical treatment may occur on ballast uptake, during vessel transit or during discharge. Examples of physical treatment of ballast water include heat treatment, ultraviolet irradiation, and ultrasonic energy.

Rigby et al. (1999, 2004) discuss the use of waste heat from the ship's main engine as a mechanism to heat ballast water and kill or inactivate unwanted organisms during vessel transit. However, it would be difficult to heat ballast water to a sufficient temperature to kill all species of bacteria due to lack of sufficient surplus energy/heat on a vessel (Rigby et al. 1999, Rigby et al. 2004). Ultrasound (ultrasonic treatment) kills through high frequency vibration that creates microscopic bubbles that rupture cell membranes (Viitasalo et al. 2005). The efficacy of ultrasound varies based on the intensity of vibration and length of exposure. Ultraviolet (UV) irradiation is another method of sterilization that is commonly used in waste water treatment. UV damages genetic material and proteins which disrupts reproductive and physiological processes. UV irradiation can be highly effective against pathogens (Wright et al. 2006).

Combined Treatment

Several treatment methods deactivate organisms by combining aspects of mechanical, chemical and/or physical treatment processes. Deoxygenation, while mainly a physical process involving the displacement of oxygen with another inert gas such as nitrogen or carbon dioxide, also has a chemical component - the addition of carbon dioxide produces a reduction in pH that enhances killing efficacy (Tamburri et al. 2006). Electrolytic or electrochemical oxidation processes combine electrical currents with necessary reactants in order to produce a wide array of killing agents. Electrolytic oxidation can produce hydroxyl radicals, capable of damaging cell membranes, or similar oxidative compounds such as ozone and sodium hypochlorite (chlorine). The degree of chemical residual formation is highly variable and dependent on the specific oxidative process being used.

Treatment Systems

Based on the methods described in Section IV (Treatment Technology Assessment Process), Commission staff compiled and reviewed information on 28 currently available shipboard ballast water treatment systems representing nine countries (Table V-1). Seventeen of these systems utilize two or more treatment methods. Multi-method systems commonly pair initial mechanical separation with a secondary chemical, physical or combined process. The systems reviewed here can be classified into four categories based on the primary treatment technology: 1) Oxidants/oxidative technologies, 2) UV systems, 3) Deoxygenation systems, and 4) Other.

Aside from mechanical separation, the most common method of treatment used in ballast water treatment systems is oxidation. Of the 28 systems reviewed, 18 use a chemical oxidant or oxidative process as the primary form of treatment (Table V-1). Specifically, six systems use chlorine or chlorine dioxide to treat ballast water, four systems use ozone, one uses ferrate, and seven use electrochemical oxidation technologies that can generate an array of oxidants including bromine, chlorine, and/or hydroxyl radicals. Of the treatment systems that have received Basic Approval for active substances from IMO thus far, all use chemical oxidants or oxidation technology to treat ballast water (Table V-1).

The second most commonly used method of ballast water treatment amongst the 28 systems reviewed is UV irradiation. Four treatment systems use UV as the primary means to kill or deactivate organisms found in ballast water. All of these systems pair UV treatment with either filtration or hydrocyclonic mechanical separation methods.

The last two categories of treatment systems reviewed by Staff include deoxygenation systems, and systems that did not fit into any of the preceding categories (“other”). Three technologies use deoxygenation as a major form of treatment, and three technologies use various methods including a non-oxidizing biocide, a heat treatment technology, and one technology using a combination of coagulation and magnetic separation (Table V-1).

Table V-1. Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
Alfa Laval	Sweden	PureBallast	combination	filtration + advanced oxidation technology (hydroxyl radicals)	IMO Basic and Final
Degussa AG	Germany	Peraclean Ocean	chemical	biocide (peracetic acid and hydrogen peroxide)	IMO Basic
Ecochlor	USA	Ecopod	chemical	biocide (chlorine dioxide)	
Electrichlor	USA	Model EL 1-3 B	chemical	biocide (sodium hypochlorite)	
Environmental Technologies Inc.	USA	BWDTS	combination	ozone + sonic energy	
Ferrate Treatment Technologies	USA		chemical	ferrate	
Greenship	Netherlands	Sedimentor + chlorination	combination	hydrocyclone + electrolytic chlorination	
Hamann AG	Germany	SEDNA System	combination	hydrocyclone + filtration + biocide (Peraclean Ocean)	IMO Basic (Peraclean)
Hi Tech Marine	Australia		physical	heat treatment	
Hitachi	Japan		physical (?)	coagulation + magnetic separation + filtration	
Hyde Marine	USA	Hyde Guardian, HBWTS	combination	filtration + UV	WA Conditional
Japan Assoc. Of Marine Safety	Japan	Special Pipe	combination	mechanical treatment + ozone	IMO Basic
JFE Engineering Corp.	Japan	JFE BWMS	combination	filtration + biocide (sodium chlorine) + cavitation	
L. Meyer GMBH	Germany		combination	filtration + disinfection liquid	

Table V-1 (Continued). Ballast Water Treatment Systems Reviewed by Commission Staff

Manufacturer	***Country***	***System Name***	***Technology Type***	***Technology Description***	***Approvals***
MARENCO	USA		combination	filtration + UV	WA General Approval
Maritime Solutions Inc.	USA		combination	centrifugal separation + UV or biocide (Seakleen)	
MH Systems	USA	BW treatment system	combination	deoxygenation + carbonation	
Mitsubishi Heavy Industries	Japan	Hybrid System	combination	filtration + electrolytic chlorination	
NEI	USA	Venturi Oxygen Stripping (VOS)	combination	deoxygenation	Type Approval (Liberia)
NKO	Korea		chemical	ozone	IMO Basic
Nutech 03 Inc.	USA	SCX 2000, Mark III	chemical	ozone	
OceanSaver	Norway	OceanSaver	combination	filtration + nitrogen saturation + cavitation	
OptiMarin	Norway	OptiMar	combination	hydrocyclone + UV	
Resource Ballast Technologies	South Africa	RBT Reactor	combination	cavitation + ozone + sodium hypochlorite	
RWO Marine Water Technology	Germany	CleanBallast!	combination	filtration + advanced electrolysis (EctoSys)	IMO Basic (EctoSys)
SeaKleen	USA	SeaKleen	chemical	biocide (menadione)	
Severn Trent DeNora	USA	BalPure	chemical	electrolytic generation of sodium hypochlorite	
Techcross Inc.	Korea	Electro-Clean	combination	electrochemical oxidation	IMO Basic

VI. ASSESSMENT OF TREATMENT SYSTEMS

The Coastal Ecosystems Protection Act required the adoption of regulations to implement performance standards for the discharge of ballast water. Since the beginning of the California ballast water program in January, 2000, forty-three percent (2649) of the 6090 unique vessels that have visited California ports have reported never discharging ballast in California waters. These vessels meet the performance standards simply by not discharging ballast. Vessels that do discharge but use nontraditional sources for ballast water (such as freshwater from a municipal source or treated grey water) will likely meet the discharge standards without the need for onboard treatment systems. Vessels that utilize coastal or ocean water as ballast will require ballast treatment prior to discharge. For these vessels, the assessment of treatment systems efficacy, availability, and environmental impacts (as required by Section 71205.3(b) of the PRC) is an important step towards understanding if systems will be available prior to the implementation of the interim performance standards beginning in 2009.

Efficacy

Evaluating ballast water treatment system efficacy is challenging due to a number of reasons. Testing methodologies in use by developers vary from system to system and occasionally between tests for a single system. The results generated from this wide array of tests differ in scale (pilot vs. full-scale) and location (laboratory vs. dockside vs. shipboard; see Appendix A). Additionally, system test results are often presented in metrics that do not lend themselves to evaluation against the California performance standards. For example, Staff encountered examples of system testing that presented results as counts of certain species per unit volume with no reference to organism size (as required in the California performance standards) and even mass of pigments per unit volume. Results presented in metrics inconsistent with the standards were noted but not included in the overall evaluation of system efficacy because it could not be determined if they met the standards. Staff expects that testing results for additional systems will emerge in metrics compatible with the California standards over time and as the standards become more widely known, now that they have been adopted through the California rulemaking process. Evaluation of system efficacy was further complicated by the overall limited availability of testing results for many systems, and the apparent lack of rigorous review of testing methods and results conducted by some companies. Without an independent and standardized approach to testing, evaluation and presentation of results, direct comparison between systems is not possible.

Despite the lack of available information, Staff reviewed all literature and numerical testing results for system potential to meet the performance standards (see Table III-1 for performance standards). The limited availability of shipboard results of system efficacy required Staff to include results from dockside and laboratory studies in their analysis. Not all studies presented test results according to organism size class (the classification system used in the California performance standards). In an effort to standardize results, Staff evaluated any data on zooplankton abundance as representative of the largest size class of organisms (greater than 50 µm in size), and phytoplankton abundance was evaluated on par with organisms in the 10 – 50 µm size class (these substitutions were solely for the purpose of this report and will not be applicable to future compliance verifications). Results presented as percent reduction in organism abundance or as concentration of pigments or biological compounds associated with organism presence were noted, but these metrics were not comparable to the performance standards.

Of the 28 technologies reviewed, specific data on system efficacy were available for only 20 (Table VI-1, Appendix A). All available information, regardless of testing location or scale, is included in this assessment.

Table VI-1. Summary of systems with available results for assessment of efficacy

Manufacturer	> 50 µm		10 - 50 µm		< 10 µm[1]		*E. coli*		Enterococci		*V. cholerae*		Source[6]
	IMO	CA	IMO	CA	IMO	CA	IMO	CA	IMO	CA	IMO	CA	
Alfa Laval	Y	Y	Y	N	N/A	Unknown	Y	Y	Y	Y			1,54
Degussa AG	Y[2]	Y[2]	Y	Y	N/A	Unknown	Y	Y					24,26,89
Ecochlor	Y	Y	Y	Y	N/A	Unknown	Y	Y	Unknown		Y	Y	50,63
Electrichlor													
ETI			Y	N	N/A	N							46,47,48,49
Ferrate Treatment Tech.								N	Y	N	N	N	15
Greenship	Y	Y	Y	Y	N/A	Unknown	Y	Y	Y	Y			16,77
Hamann AG	Y	Y	Y	Y	N/A	N							28,89
Hi Tech Marine	Unknown		Unknown		N/A								31
Hitachi													
Hyde Marine	Y	Y	Unknown		N/A	Unknown	Y	Y	Unknown				43,44,99
JAMS	Y	N	Y	Unknown	N/A	Unknown	Unknown		Unknown		Unknown		35,37,38
JFE Engineering Corp.													
L. Meyer GMBH													
MARENCO	Y	Y	Y	N	N/A	Unknown							39,40,96
Maritime Solutions Inc.													
MH Systems	Unknown				N/A						Unknown		32
Mitsubishi Heavy Ind.													
NEI	Y	Y	Y	Unknown	N/A	Unknown	Y	Y	Y	Y	Y	Y	80,81,82
NK0													
Nutech 03 Inc.	Y	Y	Unknown		N/A	Unknown							30,68
OceanSaver	Y	Y			N/A								3
OptiMarin	Y	N	Unknown		N/A	Unknown[3]							7,36,95
Resource Ballast Tech.													
RWO Marine Water Tech.	Y[4]	Y[4]	Y[5]	Y[5]	N/A								56
SeaKleen	Y	Y	Y	Y	N/A	Unknown	Y	Y	Unknown				4,14,26,44
Severn Trent DeNora	Y	Y	Y	Y	N/A	Unknown							29
Techcross Inc.	Y	Y	Y	Y	N/A	Unknown	Unknown		Unknown		Unknown		55,84

[1] Results for total bacteria count only unless indicated otherwise

[2] Peraclean Ocean concentration 200 ppm

[3] Sampling included counts of Virus Like Particles

[4] *Artemia* cysts only

[5] *Tetraselmis suecica* only

[6] Numbered sources can be found in Literature Cited section

In the largest organism size class (organisms greater than 50 µm in size), 18 systems were reviewed and 14 demonstrated potential, in at least one testing replicate, to meet the required standard of no detectable living organisms per cubic meter of discharged ballast water (Table VI-2, Appendix A1). Similar results were seen in the 10 – 50 µm size class where 17 systems were reviewed, with eight providing data for at least one test replicate that indicated compliance with the requirement of less than 0.01 living organisms per ml (Table VI-2, Appendix A2).

The results of testing on organisms less than 10 µm (bacteria and viruses) and bacterial species specific to human health standards (*Escherichia coli*, intestinal enterococci and *Vibrio cholerae*) are limited. Fifteen systems presented results of the bacterial quantification, but the majority were in a metric not comparable to the California standards and the rest did not meet the standard (Appendix A3). The lack of widely accepted methods for assessing bacterial (and viral) counts is a stumbling block to the implementation of the full suite of interim performance standards. Ten systems tested for the presence of *E. coli* in treated ballast water (Appendix A4). Eight presented results comparable to the standard and seven show potential to meet the standard. Nine systems tested for the presence of intestinal enterococci, and three systems demonstrated potential compliance (Appendix A5). Finally, six systems examined treated ballast water for toxicogenic *Vibrio cholerae* and only two systems demonstrated potential compliance with the California performance standard (Appendix A6). Results for the number (counts) of viruses in ballast water samples either pre- or post-treatment were only available for two systems examined (Appendix A7).

Table VI-2. Summary of Potential Treatment System Performance with Respect to California Performance Standards

	Organisms Greater than 50	Organisms 10 – 50	Organisms less than 10	*Escherichia coli*	Intestinal enterococci	*Vibrio cholerae*
Total Systems with Results to Review[1]	18	17	Bacteria: 15 Viruses: 2	10	9	6
Number Systems that Meet Standard[2]	14	8	Bacteria: 0 Viruses: 0	7	3	2

[1] Of out of the 28 total systems assessed in this report, only 20 had testing results available for review. Not all 20 covered testing under each of the organism size classes. The total number of systems with results in a given size class is indicated in this category.
[2] This category reflects the number of systems with at least one replicate of system testing in compliance with the California performance standards (see Table III-1 for standards).

The lack of available results demonstrating shipboard treatment system performance was a major hindrance to assessing ballast water treatment system efficacy under real-world conditions. Of the 28 treatment systems reviewed, only 10 presented results from sea trials onboard vessels (Appendix A). Even within the shipboard results, however, testing varied in scale and method. Some systems have been tested using only one or two of the many available ballast tanks onboard a vessel. Other technologies have tested system efficacy across multiple ballast tanks, but only on a single voyage. A thorough investigation of system efficacy should examine ballast water treatment system performance over multiple voyages encompassing different seasons and water quality conditions.

Overall, only 20 treatment systems had results available for analysis of system efficacy; the potential for the remaining 8 systems to meet the California standards is not clear at this time. For those systems with results, four systems demonstrated potential to meet 4 out of seven performance standards size classes, two systems met 3 size classes, five systems met 2 size classes and three systems met just 1 size class (Table VI-1, Appendix A). Current law states that upon implementation of the California performance standards, discharged ballast water must meet all organism size class requirements. Treatment systems currently exist that are demonstrably capable of and/or have the potential to meet at least some of the organism size classes of the California performance standards, but at this time no systems meet all size classes.

Availability

An assessment of the availability of ballast water treatment systems requires knowledge of many elements including market demand, government approval of systems, the number of vessels impacted by the performance standards, and commercial availability. These issues are inextricably linked. Commercial availability is not simply a function of whether or not a system is available for purchase; it is also dependent on the sufficient production of systems to meet demand and the availability of customer support. System availability is also influenced by the presence of an available market (i.e. demand) to purchase treatment systems. This market, in turn, will depend upon the development of mechanisms for systems approval, particularly at the federal and international levels, as vessel operators may be hesitant to purchase systems without government assurance that such systems will meet applicable standards. Ultimately, however, the availability of treatment systems is linked to the capability to meet the standards. The aforementioned elements impacting system availability apply only to systems that demonstrate compliance.

Industry Demand

The California performance standards have a phased implementation schedule that mirrors that of the IMO Convention (see Table III-2). The phased implementation provides greater time for existing vessels to plan and execute retrofits to existing structures and machinery. All new vessels built on or after January 1, 2009 with a ballast water capacity less than 5000 MT that discharge in California waters must meet the performance standards. The number of new vessels that must meet the performance standards beginning in 2009 will greatly influence how strongly treatment developers will have to push to have their systems available for sale. New vessels with a ballast capacity greater than 5000 MT must comply by 2012. Lloyd’s Register (2007) estimates that in 2009, construction will commence on 540 new vessels worldwide with a ballast capacity of less than 5000 MT. Exactly how many of those vessels will ultimately operate and discharge ballast in California waters is difficult to determine, however the numbers are expected to be relatively small. Examination of the number of vessels that have previously discharged in California provides some insight. Between January 1, 2000 and June 30, 2007, nearly 900 unique vessels with a ballast water capacity less than 5000 MT arrived in California and only 324 of those discharged ballast into California waters (Figure VI-1). Presuming a 20-year vessel replacement cycle, approximately 5% (45) of these almost 900 vessels may be replaced by new vessels and be required to meet the performance standards in 2009, and an even smaller number will discharge in California waters and require treatment system usage (K. Reynolds, pers. comm.). In the class of vessels with a ballast water capacity greater than 5000 MT, approximately 5250 unique vessels arrived, and 3167 discharged, in California waters between January, 2000 and June, 2007 (Figure VI-1). Again, a small percentage of these will also likely be replaced with new vessels and will be required to meet the performance standards beginning in 2012. Clearly, a much smaller number of new vessels will be required to meet the standards beginning in 2009 than in 2012; however, the precise number is less clear.

Because of the phased implementation schedule, existing vessels are affected by the performance standards much later than are newly built vessels. Existing vessels in the 1500-5000 MT size class must meet the standards in 2014, and all others must meet the standards in 2016. The specific number of existing vessels that will be subject to the standards beginning in 2014 is difficult to determine at this time. Traffic to California ports is on the rise (Falkner et al. 2007), but many older vessels may be scrapped in the intervening years before the standards take effect for existing vessels. Determining industry demand is further complicated by purchase timing (i.e. when a vessel chooses to purchase a treatment system). Many vessels, particularly existing ones with later implementation dates, may choose to purchase a system earlier than required so that installation dovetails with drydock and repair schedules. In this case, estimates of demand based solely on the standards implementation dates are likely inaccurate.

Commission staff will continue to follow trends in vessel visits to California and treatment system purchase and installation, particularly as the performance standards are implemented for newly built vessels, and will reassess system availability for existing vessels in future reports.

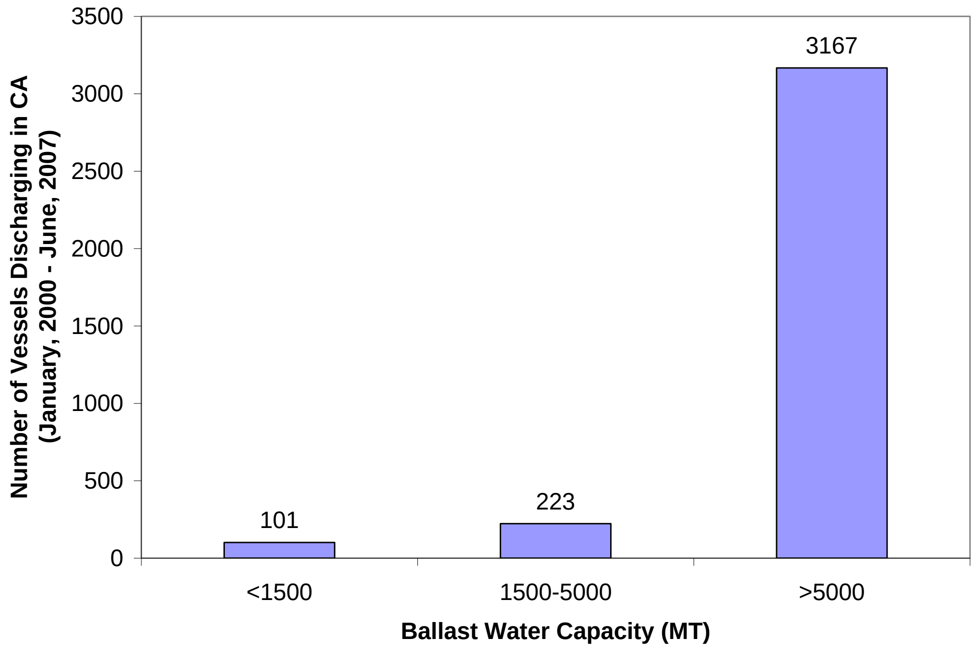

Figure VI-1. Number of vessels discharging in California waters between January, 2000 and June, 2007 as a function of ballast water capacity (MT).

Commercial Availability

System developers will need to have systems commercially available by the time the initial interim performance standards take effect in 2009. Twenty treatment technology developers provided Lloyd's Register (2007) with an actual or anticipated date of commercial availability. One company reported commercially availability in 2000. Of the remaining 19, eight were available in 2006, five are (or expect to be) ready in 2007, three anticipate commercial availability in 2008 and three in 2009. Similar data collected by Commission staff indicate at least five technologies are commercially available now and another four may be ready for commercial release by 2008, well ahead of the 2009 implementation date.

Treatment developers will also need to produce sufficient quantities of systems to meet market demand. Several of the large, multinational technology developers already produce many other products for the maritime industry and have a pre-existing infrastructure in place that may be modified to globally produce and support ballast water treatment systems (K. Reynolds, pers. comm. 2007). However, it is more difficult to gauge the ability of small technology developers to meet projected needs, or if collectively, all treatment developers will be able to meet the needs of the shipping fleet. Treatment developers may be able to space out delivery of systems for new vessels with a ballast capacity less than 5000 MT over a couple of years while infrastructure and production are brought up to speed, as even the largest marine corporations require significant lead time for existing marine product lines (K. Reynolds, pers. comm. 2007). While vessels in this size class are subject to the standards as of 2009, the construction of large commercial vessels can take several years, and many of those vessels may not actually be ready for treatment system installation and operation until 2010 or later.

System support is equally as important as commercial availability. Following installation, system developers will need to have personnel and infrastructure in place to troubleshoot and fix problems that arise during system operation. Maritime trade is a global industry, and vessel operators will need to have support for onboard machinery whether their vessel is in Los Angeles, Shanghai, or somewhere in between. In the Glosten Associates (2006) assessment of five treatment developers, three were prepared to offer worldwide support, while plans for service were under development for the remaining two. The Lloyd's Register (2007) report does not address the issue of after-purchase support of systems. The initial influx of systems into the marketplace will no doubt challenge developers to provide adequate service. Larger companies entrenched in the maritime logistics or equipment industries may already be prepared to respond to technological challenges and emergencies as they arise, but smaller ballast water treatment developers may face an initial period to ramp up service and access replacement parts. It is currently unclear if system support service will be adequate as the first of California's performance standards is implemented in 2009, and if a lack of service could impact system availability.

Commercial availability should not, however, at any time be confused with the capability of systems to meet the standards. Systems that may be deemed commercially available and ready for sale by technology developers must demonstrate system efficacy to vessel operators who will purchase those systems and to regulatory government agencies.

Market Availability

The availability of ballast water treatment systems is not only a function of commercial availability but also of market demand to purchase those technologies. Previous discussions addressed one aspect of demand - the numbers of vessels that will be required to meet the performance standards beginning in 2009. However, demand may also be influenced by the availability of systems that have received government approval to operate in a given water body.

In the U.S., the lack of a regulatory framework for the approval of ballast water treatment systems at the federal level is a major hindrance to the demand for systems. While California law requires initial compliance with the interim performance standards in 2009, shipping companies may be hesitant to purchase treatment systems with little or no assurance that the system will be permitted to operate in federal waters. Unless the USCG approves treatment systems prior to 2009, a vessel intent on discharging ballast in California arriving from outside of the 200 nm Exclusive Economic Zone will need to conduct a mid-ocean exchange to comply with federal ballast water management requirements and will additionally be required to treat that water to meet California requirements. This conflict in ballast management regulation between federal and state governments will no doubt cause confusion and temper demand to install treatment systems on vessels. Other states have begun to address the approval of treatment systems despite the lack of federal guidance. Washington and Michigan have preliminary approval processes for treatment systems in place. These states will encounter the same conflict between state and federal requirements until such time that the Federal government develops standards and approves technologies to meet those standards. The Commission supports the adoption of California's standards by other states and the Federal government and hopes that the USCG will accept technologies that meet the California standard as sufficient to meet USCG requirements.

Despite the potential conflict between federal and state requirements, Staff has begun developing guidelines (see Section III for initial discussion of guidelines) for treatment technology developers, in conjunction with third-party independent testing laboratories, to self-certify that their systems will meet California standards. These guidelines may serve as a template for use by developers or third-party independent laboratories to test systems that may be sold for use on vessels operating in California waters. In turn, vessel operators will have assurance that the systems they purchase have been evaluated specific to the California standards. The development of the testing guidelines has been initiated by Commission staff with a projected completion date of late-2008.

The development of testing guidelines by Commission staff is an important step to assist with the assessment, purchase and installation of treatment technologies for vessels that will operate in California, however, the guidelines will do little to facilitate the market for treatment systems at the federal or international level. Shipping companies may be unwilling to spend million of dollars purchasing and installing systems without knowledge that those systems meet federal and international requirements, and the demand for treatment technologies will likely remain sluggish until certification and legislative issues are settled.

Environmental Impacts

The assessment of environmental impacts associated with the release of treated ballast water will require agreed upon whole effluent testing procedures and criteria and mechanisms to evaluate potential impacts on designated beneficial uses (e.g. recreation, fisheries, fish/wildlife habitat) in the State's receiving waters. The development of these procedures will require cooperation amongst local, state, and federal agencies with water quality jurisdiction and expertise. Thus far such involvement has been limited in California. However, as a beginning point, many of the active substances/biocides used in ballast water treatment systems are already in use in other waste water and industrial applications. Therefore, assessment of treatment technologies for toxicological impacts may be eased by an initial examination of current discharge criteria. Furthermore, the IMO and State of Washington have developed procedures to assess the environmental impacts of chemicals in treatment systems, and a review of these programs may provide additional insight into the safety of some treatment systems. Ultimately however, California must develop methods to assess potential environmental and water quality impacts of discharging treated ballast which appropriately address applicable water quality objectives (including criteria for chemical residuals, water temperature, salinity, level of entrained sediments, and organic content) for California's receiving waters.

International Maritime Organization

As discussed in Section III (Regulatory Overview), the IMO has established an approval process for treatment technologies using active substances (i.e. chemicals) to ensure systems are safe for the environment, ship, and personnel. The two-step approval process is comprised of initial "Basic Approval" utilizing laboratory test results to demonstrate basic environmental safety followed by a Final approval process to evaluate the environmental integrity of the full-scale system. For California, examination of the IMO active substance approval process may provide an initial assessment of a treatment system's broad-scale environmental safety prior to the development of testing methods specific to State water quality requirements.

The Guideline G9 of the Convention requires applicants to provide information identifying: 1) Chemical structure and description of the active substance and relevant chemicals (byproducts); 2) Results of testing for persistence (environmental half-life), bioaccumulation, and acute and chronic aquatic toxicity effects of the active substance on aquatic plants, invertebrates, fish, and mammals; and 3) An assessment report that addresses the quality of the tests results and a characterization of risk (MEPC 2005b). Systems that apply for Basic and Final Approval are reviewed by the IMO Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) –

Ballast Water Working Group (BWWG) in accordance with the procedures detailed in Guideline G9. The Guideline does not address system efficacy, only environmental safety (MEPC 2005b).

Federal

No formal evaluation of ballast water treatment systems currently occurs at the federal level. Experimental testing and evaluation of systems proceeds through the USCG Shipboard Testing and Evaluation Program (STEP; see Section III, Regulatory Overview for more information). Environmental compliance requirements associated with STEP participation include: 1) Compliance with the National Environmental Policy Act (NEPA) process; 2) Due diligence by the applicant in providing requested biological and ecological information and obtaining necessary permits from regulatory agencies; and 3) A provision that systems found to have an adverse impact on the environment or presenting a risk to the vessel or human health will be withdrawn from the program (USCG 2006). Systems that use novel, proprietary chemicals not currently in use in large-scale applications will require Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registration through EPA and a full toxicological impact analysis before assessment can progress.

State of Washington

The Washington State Department of Ecology developed a framework for the evaluation of effluent from ballast water discharge in 2003 and revised it in 2005. The "Laboratory Guidance and Whole Effluent Toxicity Test Review" (Washington Department of Ecology 2005) discusses information and procedures related to whole effluent toxicity testing regulations, test review, species and test conditions, and includes appendices relevant to particular cases and or situations (e.g. Appendix H: Establishing the Environmental Safety of Ballast Water Biocides). These tests are based on EPA toxicity testing procedures and require reporting in line with EPA toxicity testing manuals.

The results of the toxicity testing are used to set system discharge conditions such as maximum concentration or minimum degradation time (R. Marshall, pers. comm. 2007).

Following toxicity testing, systems are examined by the Washington Department of Fish and Wildlife, in conjunction with the Department of Ecology, for their ability to remove unwanted organisms under the conditions established as toxicologically safe (R. Marshall, pers. comm. 2007). Thus far, four systems have completed toxicity testing in accordance with Washington requirements (Table VI-3).

California

California does not have a formal review process for water quality impacts associated with ballast water treatment technologies. Staff has reviewed toxicity studies on treatment technologies that have been provided to the IMO, the State of Washington and the Commission. These reviews have provided initial indicators of potential environment impacts. Treatment systems wishing to operate in California waters must ultimately demonstrate compliance with all applicable water quality requirements as determined by the SWRCB. At this time, Commission staff are consulting with the SWRCB to identify all appropriate water quality standards and control plans.

The current court case addressing the regulation of vessel discharges (including ballast water) under the Clean Water Act may impact the criteria for evaluation of treated ballast water in California (see Section III, Regulatory Overview for summary of EPA vs. Northwest Environmental Advocates et al.). If EPA loses its appeal, SWRCB may attempt to regulate ballast water discharges. In that situation, SWRCB would also evaluate water quality impacts associated with treated ballast water under the State's NPDES program beginning as early as September 30, 2008. Until such time that jurisdiction over ballast water is settled, however, Staff will continue to consult with SWRCB staff to identify applicable water quality requirements and develop a review process for ballast water treatment systems.

Environmental Assessment of Treatment Systems

Staff has compiled environmental assessment reports and toxicity studies reported to the IMO and State of Washington, including any additional toxicity work as made available to the Commission, to assess the treatment systems for environmental impacts. While these studies provide an initial indicator of system environmental safety, they have not been conducted with California regulations and requirements in mind and a formalized environmental review may still need to occur when all appropriate California water quality requirements are identified.

Of the 28 treatment systems reviewed, 21 use an active substance (biocide) in the treatment process, and will thus require toxicological testing to ensure environmental safety before the systems can be used in State waters (Table VI-3). Systems that do not use active substances (such as those using UV) will not require toxicological testing to operate in California, however, these systems must still be reviewed for efficacy and ship and personnel safety.

Toxicity testing results for four systems were submitted to the Washington Department of Ecology for review, and three were recommended for conditional approval (which must be granted by the Washington Department of Fish and Wildlife) within specified limits for discharge concentration. One additional system was recommended for approval for the purposes of one onboard experiment (Table VI-3). Eight systems that use active substances to meet the IMO performance standards have applied for Basic Approval and six of those systems have been approved by MEPC based on recommendations from the GESAMP-BWWG (Tables V-1 and VI-3). Only one system has applied and was granted Final Approval by the MEPC thus far. Application for environmental review of system toxicity through the IMO and State of Washington is not mutually exclusive. To date, one system has been reviewed and approved by both administrations.

Table VI-3. Summary of toxicity testing for treatment systems that use active substances. Grey fill denotes systems that do not utilize active substances.

Manufacturer	***Toxicity Testing Conducted?***	***Toxicity Related Approvals***
Alfa Laval	√	IMO Basic, IMO Final
Degussa AG	√	IMO Basic, Rec. for WA Conditional[1]
Ecochlor	√	Rec. for WA Conditional[1]
Electrichlor		
Environmental Technologies Inc.		
Ferrate		
Greenship		
Hamann AG	√	IMO Basic (Peraclean)
Hi Tech Marine	N/A	N/A
Hitachi		
Hyde Marine	N/A	N/A
Japan Assoc. Marine Safety	Incomplete	IMO Basic
JFE Engineering Corp.		
L. Meyer GMBH		
Maritime Solutions Inc.		
MARENCO	N/A	N/A
MH Systems	N/A	N/A
Mitsubishi		
NEI	N/A	N/A
NK0[2]	√	IMO Basic
Nutech 03 Inc. [2]	√	
OceanSaver	N/A	N/A
OptiMarin	N/A	N/A
Resource Ballast Technologies	√	
RWO Marine Water Technology	√	IMO Basic (EctoSys)
SeaKleen	√	WA Single Test[3]
Severn Trent DeNora	√	Rec. for WA Conditional[1]
Techcross Inc.	√	IMO Basic

[1] The Washington Department of Ecology Water Quality Program has recommended Conditional Approval of this system to the Washington Department of Fish and Wildlife. As of the writing of this report, approval has not been granted.
[2] NKO and Nutech 03 Inc. have partnered (NK03) and any joint status of their technology approvals was not known at the writing of this report.
[3] SeaKleen was given a one-time approval to conduct a single test of their system.

In total, 12 of the 21 systems that use active substances have submitted information on toxicological testing to the IMO, the State of Washington, or both. Ten of those systems have received some form of approval as of August 2007. Treatment technology developers wishing to operate in California waters will still need to demonstrate compliance with applicable California water quality standards and regulations, and at this time the procedures to assess environmental impacts are still under development.

Economic Impacts

An assessment of the economic impacts associated with the implementation of performance standards and the use of treatment technologies requires consideration not only of costs associated with the purchase, installation and operation of treatment systems, but also the impacts associated with the control and/or eradication of NIS if performance standards are not met. As discussed in the Introduction (Section II), the U.S. has suffered major economic losses as a result of attempts to control and eradicate NIS (aquatic and terrestrial; Carlton 2001, Lovell and Stone 2005, Pimentel et al. 2005). The rate of new introductions is increasing (Cohen & Carlton 1998, Ruiz & Carlton 2003) which suggests that economic impacts will likely increase as well.

California had the largest ocean economy in the U.S. in 2004, ranking number one for employment, wages and gross state product (NOEP 2007). California's natural resources contribute significantly to the coastal economy. For example, in 2005 total landings of fish were over 440 million pounds, bringing in $116 million (NOEP 2007). Squid, the top revenue-generating species in 2005, brought in almost $31.5 million (NOEP 2007). The health of coastal natural resources are also closely tied to the tourism and recreation industries, accounting for almost $12 billion in California's gross state product in 2004 (NOEP 2007). NIS pose a threat to these and other components of California's ocean economy including commercial fisheries, aquaculture, sport and recreational fisheries, tourism and recreation, and education.

The use of ballast water treatment technologies to combat NIS introductions will involve economic investment on the part of ship owners. This investment in treatment systems reflects not only initial capital costs for the equipment and installation, but also the continuing operating costs for replacement parts, equipment service and shipboard energy usage. Cost estimates are strongly linked to vessel-specific characteristics including ballast water capacity, ballast pump rates, normal operational needs, and available space. Additionally, the retrofit of vessels already in operation (existing vessels) with ballast water treatment technologies may cost significantly more than installation costs for newly built vessels due to: 1) The necessity to rework existing installations (plumbing, electric circuitry); 2) Non-optimal arrangement of equipment that may require equipment be broken into pieces and mounted individually; 3) Relocation of displaced equipment; and 4) The time associated with lay-up (K. Reynolds 2007, pers. comm.). Nonetheless, the use of these treatment technologies will likely help minimize or prevent future introductions of NIS and may relieve some of the future economic impacts associated with new introductions.

Many treatment technology developers are hesitant to release costs at this point because system prices represent research and development costs and do not reflect the presumably lower costs that would apply once systems are mass produced. In a 2007 report assessing the status of ballast water treatment technologies by Lloyd's Register, only 11 of 24 technologies profiled provided estimates of system capital expenditures (equipment and installation) and half (12) provided estimates of system operating expenditures (parts, service, and energy usage; Table VI-4). Capital expenditure costs are dependent on system size. A 200 cubic meters per hour (m^3/h) capacity system may require an initial capital expenditure between \$135,000 and \$650,000 with an average of cost of \$274,200 (Lloyd's Register 2007). A 2000 m^3/h capacity system ranges from \$165,000 to \$1,175,000 with an average cost of \$542,500 per system (Lloyd's Register 2007). Operating costs range from \$0.005 m^3/h of treated ballast to \$0.20 per m^3/h with an average of \$0.032 per m^3/h (Lloyd's Register 2007).

Relative to the cost of a newly built vessel, treatment systems may increase the cost of a vessel by 1-2%. For example, a new 8500 TEU (twenty-foot equivalent unit) container ship built by Seaspan Corporation costs approximately \$132.5 million per vessel (Seaspan Corporation 2007). Installation of the most expensive currently available treatment system at \$1.175 million (as indicated in Table VI-4) would increase the cost of that vessel by less than one percent. Many treatment technology developers claim that their systems will last the life of the vessel, so the capital costs of treatment systems should be a one-time investment.

Table VI-4. Summary of capital and operating cost data for select treatment systems. Unless otherwise denoted with **, source of data was Lloyd's Register 2007, Ballast Water Treatment Technology – Current Status.

Manufacturer	Capital Expenditure *(Equipment & Installation)*			Operating Expenditure
	200 m3/h *($ in thousands)*	**2000 m3/h** *($ in thousands)*	**Other** *($ in thousands)*	*($ per m3/h, unless otherwise noted)*
Alfa Laval				$0.015/m^{3**}$
Ecochlor	260	400		0.08/MT**
Electrichlor	350			0.019
ETI		500		0.005
Greenship	147	1175		
Hamann AG				0.2
Hi Tech Marine			16.5 – 300** *(equipment only)*	0.003/MT**
Hitachi				
Hyde			174 – 503**	0.01
JFE Engineering				0.04
MARENCO	135	165		0.1
MH Systems	650	950		0.06
Mitsubishi				
Japan Assoc. Marine Safety			100** *(installation only)*	0.15
NEI	150	400		0.05
Nutech 03				
OceanSaver				0.06
OptiMarin	400			
Resource Ballast Technologies	150	250		
RWO Marine				
Severn Trent	350	500		0.02
Techcross	150			0.03/MT**

**Denotes data that was found in references other than the 2007 Lloyd's Register report.

While the economic investment by the shipping industry in ballast water treatment technologies is not negligible, it is clear that damages from NIS are extremely costly in the U.S. Experts suggest that, when compared to the major costs to control and or eradicate NIS, the costs to treat ballast water may be minimal. Treating ballast water with treatment technologies will help to prevent further introductions and lower future costs for control and eradication. Additional studies will be necessary to obtain actual economic impacts associated with treating ballast water.

VII. CONCLUSIONS

Treatment systems that remove or inactivate organisms from ballast water will likely meet California's performance standards in the near future. However, given the short time remaining before the first implementation date for vessels with a ballast water capacity less than 5000 MT, and the need for the development of efficacy and environmental testing procedures before a system should be utilized in California waters, it is unlikely that systems will be available by 2009.

On a system-by-system basis no single technology demonstrated the capability to meet more than four (out of seven) of California's performance standards. Information for 28 different treatment technology systems was evaluated for their efficacy, availability and environmental impacts. Testing was either not performed or data were not available for 8 systems. For the remaining 20, it was often impossible to compare the available data for a single system against all of the organism size classes specified by California's performance standards because the methods used to evaluate efficacy were variable. In addition, only 10 technologies for which data was available have been tested onboard vessels during sea trials. Clearly, standardized testing and evaluation guidelines should be developed so results are in an appropriate format, particularly for the <10 µm size class. Standardized protocols will allow all systems to be evaluated on an even playing field.

Efficacy considerations aside, several companies are, or will soon be capable of producing treatment systems in a commercial context. Five to seven companies claim their systems are already commercially available, and an additional four to six claim that they are poised to launch systems commercially by 2009. At least three appear equipped to offer worldwide troubleshooting support for systems, and two additional companies will soon have service support in place.

In application, however, the issue of availability is dependent on a sequence of events for which the timing of each is unclear. Protocols must be standardized so systems are tested adequately, equitably, providing results that are comparable against California's performance standards. A process must also be in place to evaluate environmental impacts. A treatment system must then prove to meet the standards while operating within acceptable environmental limits. Once a system demonstrates efficacy, availability hinges on companies being able to install sufficient functioning systems for the quantity of vessels constructed on or after 2009.

Though the environmental impacts for many systems have been, or are in the midst of being evaluated by the IMO and/or Washington State, and many borrow from established wastewater treatment technologies, none have been evaluated specifically against the water quality criteria and regulations in California. The only environmental impact data currently available were for those systems seeking approval through the IMO or for use in Washington waters. Though several of these systems utilize technologies that have been deemed acceptable for wastewater treatment, their appropriateness for California waters has not yet been evaluated against the State Water Resources Control Board's and Regional Water Quality Control Board's water quality control plans and regulations. The establishment of an evaluation procedure or process for environmental impacts is as essential as protocols to assess efficacy, particularly for systems that use active substances (i.e. chemicals). Clearly, the environmental and water quality impacts from these treatment systems should be examined critically, with substantial review from the agency/agencies with the expertise and jurisdiction to ensure that discharges of treated ballast water meet California's water quality requirements.

VIII. LOOKING FORWARD

The infancy of the field of ballast water management, specifically related to treatment system development is apparent. As stated previously, the lack of performance standards has often been cited as a primary factor impeding the progress of technology development. Internationally, performance standards were only adopted in early-2004 and they have yet to be ratified. California's much stricter standards were only adopted by legislation in late-2006 and codified in regulation in October, 2007. The federal government has yet to adopt performance standards. So while the issue of NIS and ballast water management has been regulated to some degree since 1996, adoption of numeric standards is very recent.

As required by the Coastal Ecosystems Protection Act (Section 71205.3a of the PRC), Commission staff has adopted regulations governing interim and final performance standards for the discharge of ballast water. This report reviews the efficacy, availability and environmental impacts of currently available technologies and fulfills the requirements for the initial report assessing ballast water treatment technologies (Section 71205.3b of the PRC). The Act has strengthened the ability of the Commission to prevent NIS introductions and has increased agency responsibilities, specifically in regards to treatment technology assessment and the verification of vessel compliance with the performance standards.

The Marine Invasive Species Program staff is currently engaged in the following activities in order to continue to fulfill the Commission's legislative directive to, "move the state expeditiously toward the elimination of the discharge of nonindigenous species into the waters of the state".

1. Develop guidelines to assist treatment technology developers and independent third-party laboratories with the testing and evaluation of treatment systems relative to California's performance standards.

Standardized testing guidelines will assist and encourage developers and independent laboratories to use appropriate methods when evaluating their treatment systems against California's performance standards. Treatment developers may then self-certify that their systems will meet California's requirements. This would provide ship owners with information and some assurance regarding which treatment technologies would best meet their needs. In this review, the full potential for many systems to meet the performance standards could not be determined because data were not presented in metrics consistent with the performance standards. Guidelines for the testing of systems will provide a suggested template for the testing of treatment systems and may increase the demand for systems that are certified by treatment developers. These guidelines are expected to be made available to industry in mid- to late-2008.

2. Develop verification protocols to assess vessel compliance with the performance standards.

Staff must develop protocols to verify vessel compliance with the performance standards. This process will be enhanced by the use of the best available methods for organism enumeration in terms of ease of use, cost effectiveness, accuracy, precision and acceptance by the scientific community. The lack of widely used and accepted methods for counting organisms in the less than 10 µm size class will be particularly problematic.

Additional procedures will be required for on-site sampling, the handling of samples between vessel and testing laboratory (chain of custody), mechanisms for the identification and approval of independent laboratories to conduct the sample analysis, and requirements for reporting of compliance from laboratory to the Commission. The development of the verification protocols and the associated rulemaking process is expected to be completed in late-2008.

3. Work in consultation with the SWRCB to identify applicable water quality requirements for ballast water treatment technologies and provide technology developers with a guidance document to ensure system compliance with applicable California laws.

Twenty-one of the 28 technologies reviewed in this report utilize active substances to kill or inactivate ballast water organisms. As specified in the California Coastal Ecosystems Protection Act of 2006, it is important that such systems be reviewed for environmental impacts, including effects on water quality. As the state agency with the authority and expertise to evaluate and enforce water quality requirements under the Clean Water Act, the State Water Resources Control Board plays an integral role in this regard. The SWRCB and the Commission will work to identify the California water quality requirements that are applicable to ballast water treatment systems. This information will be incorporated into a guidance document and passed on to treatment developers so that they may ensure that their systems will be in compliance with California's water quality requirements.

4**. Support the alignment of testing and evaluation guidelines amongst all U.S. West Coast states.**

Commercial shipping is an international industry; any single ship may operate throughout several regions of the world. Ideally, performance standards should align both at the federal and international level and is preferable to a patchwork of standards adopted by individual states. Barring uniformity at larger scales, standards aligned along the U.S. West Coast would be beneficial for both industry and participant states. Even in cases where performance standards differ, it may still be possible to use the same testing and evaluation procedures to assess the effectiveness of treatment technologies. If all West Coast states encouraged technology developers to use the same testing and evaluation procedures, it would provide more uniform and useful information to ship owners.

While Staff will continue to work with Oregon, Washington, other states, and the federal government on the alignment of performance standards and treatment technology testing and evaluation guidelines and protocols, the Commission will proceed as required to fulfill its mandates under the Coastal Ecosystems Protection Act.

IX. RECOMMENDATIONS TO THE LEGISLATURE

1. Change the implementation date for new vessels with ballast water capacity less than 5000 metric tons from 2009 to 2010, and require the Commission to prepare an update of this report on or before January 1, 2009.

It appears that treatment systems should be able to meet most of California's performance standards in the near future, however, none currently demonstrate the capacity to meet all of the standards. Commission staff have begun developing guidelines, which are expected to be completed in late-2008, for the testing and evaluation of treatment systems by technology developers and independent third-party laboratories. This should aid in the testing process and provide treatment developers with a mechanism to self-certify that their system meets the California discharge standards. Simultaneously, Commission staff will require time to develop protocols to verify vessel compliance with the performance standards and identify laboratories and prepare them for the process of analyzing compliance sampling on vessel discharges. These verification protocols are expected to be completed and approved through the California rulemaking process by late-2008. While efforts will be made to keep industry appraised of the development of these guidelines and protocols as they progress, the period of time remaining for testing before the 2009 deadline would be prohibitively short. Additionally, the state must have time to identify and make industry aware of any and all applicable water quality criteria and regulations governing the discharge of treated ballast water. It is unlikely that all of this could be completed prior to the initial implementation date in 2009.

2. Authorize the Commission to amend the ballast water reporting requirements via regulations.

Section 71205(D) of the PRC currently requires reporting of ballast water management information needed to support regulation via ballast water exchange or alternative ballast water management methods. As treatment systems come online, it will be important for the Commission to acquire different types of information including the timing of and requirements for treatment system use, deviations from suggested system operation, and certifications for operation from vessel classification societies and other organizations/agencies. An expansion of the vessel reporting requirements may be necessary for Commission staff to gather information and generate future recommendations regarding the implementation of the performance standards and the evaluation and use of ballast water treatment systems. The Commission should be authorized to amend ballast water reporting requirements to meet these needs.

3. Support continued research promoting technology development.

Ballast water treatment is a fledgling industry that will need to undergo significant development as California's Performance Standards are progressively implemented and as new vessel types are built. In 2012, the standards will go into effect for new vessels with the largest ballast water capacity (over 5000 MT), and technologies will need to be able to effectively inactivate organisms under high volume and pump rate conditions. Existing vessels built before 2009 will need to be retrofitted for approved treatment systems by 2014 or 2016 (depending on ballast water capacity). Those technologies must be installable under limited space conditions, and must be able to integrate with the existing engineering of ships (piping, electrical, computer, etc.). While several of the systems evaluated in this report meet or come close to meeting many of California's Standards, many were not installed and tested on ships. It is not clear if they can be viably installed on existing vessels. Finally, as the zero discharge deadline approaches in 2020, treatment technologies must be available that kill or inactivate all organisms, in all size classes, or vessels must be operated/constructed so that they do not need to discharge ballast water. The research and development needed to reach these goals under these timelines will require substantial financial resources, and should be supported by the Legislature.

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